# FORECASTER'S FORUM

## IFPS and the Future of the National Weather Service

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## 1. Introduction

The National Weather Service (NWS) is now in the midst of a major paradigm shift regarding the creation and distribution of its forecasts. Instead of writing a wide array of text products, forecasters will make use of an interactive forecast preparation system (IFPS) to construct a 7-day graphical representation of the weather that will be distributed on grids of 5-km grid spacing or better (Ruth 2002). To create these fields, a forecaster starts with model grids at coarser resolution, uses "model interpretation" and "smart" tools to combine and downscale model output to a high-resolution IFPS grid, and then makes subjective alterations using a graphical forecast editor. Such gridded fields are then collected into a national digital forecast database that is available for distribution and use. The gridded forecasts are finally converted to a variety of text products using automatic text formatters.

There is little question that the NWS must trend toward graphical forecast products if it is to remain effective and relevant. First, only graphical/gridded distribution can effectively communicate the detailed spatial/temporal information that is becoming available as model resolution increases, knowledge of local weather features advances, and observing systems improve. Second, gridded forecasts are required for effective distribution over the Web and through the media. Third, many new forecast applications (such as transportation applications and automated warning systems) require a digital/gridded forecast feed.

Although graphical tools clearly have a major place in the forecast office of the future, the current implementation of IFPS by the NWS has major conceptual and technical deficiencies that threaten to undermine the institution's ability to provide skillful forecasts to the public and to other users. This paper will examine some

of these problems and will provide some suggestions regarding the forecast preparation system of the future.

## 2. Problems with IFPS

### a. Deterministic versus probabilistic local forecasting

One of the most serious issues with IFPS is that its current design anchors the NWS to an outdated, essentially deterministic, view of forecasting that is inconsistent with the rapidly developing science and capability of modern numerical weather prediction. Considering the substantial uncertainty in mesoscale forecasts, particularly mesoscale forecasts out several days, it makes little sense to base a suite of operational products on a single deterministic forecast for 7 days into the future. Such forecasts generally have rapidly decreasing skill in time regarding the position and amplitude of important features. Thus, forecasts of specific features would frequently be wrong and could undermine public and user confidence in NWS products. A deterministic approach to forecasting (and the use of IFPS to present a single rendition of reality) is more reasonable for a short-term forecast (a 0–12-h "nowcast"), which is heavily based on observed features whose evolution can be estimated through extrapolation and persistence of existing conditions. However, there are some short-term forecast situations (e.g., convection) that may still require a probabilistic approach.

An alternative to a single deterministic forecast is now becoming available: calibrated probabilistic products based on mesoscale ensemble forecasts. Past a certain projection time (approximately 12 h), probabilistic, ensemble-based forecasts should be the foundation for graphics and text generation. However, IFPS in its current form is not built to ingest or use ensemble forecasts or to consider probabilistic information other than simple probability-of-precipitation forecasts. Probabilistic products for all key variables should have been the centerpiece of IFPS; in reality, this is not the case.

### b. Downscaling and associated technical issues

In the IFPS system, forecasters are required to downscale model forecasts to a 5-km grid, with the option of

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using even smaller grid spacing. However, the current downscaling approach of the IFPS system is highly problematic. It starts with National Centers for Environmental Prediction (NCEP) forecast grids of degraded resolution because of limited available bandwidth. For example, instead of receiving the full-resolution 12-km Eta Model forecast grids, NWS offices are provided 40-km grids, with only a handful of full-resolution fields at the surface. Forecasters must then downscale the model grids to 5-km resolution, either manually or with the help of smart tools. One such smart tool uses standard lapse rates and high-resolution terrain to extrapolate temperature from model elevations to station heights. Others allow a forecaster to alter forecast fields over land, water, or for some elevation bands, or to adjust regional values based on sparse model-output-statistic (MOS) forecasts. Even if such tools are marginally useful for some parameters (e.g., temperature), they are completely inadequate for others (e.g., winds), particularly in areas of complex terrain or near coastlines.

The use of subjective downscaling may have made sense a decade ago, when numerical models lacked the resolution to simulate regional features realistically and mesoscale detail was entirely the contribution of the forecaster, but the situation is different today, with high-resolution models such as Eta, the fifth-generation Pennsylvania State University–National Center for Atmospheric Research Mesoscale Model (MM5), and the Weather Research and Forecasting (WRF) Model producing realistic mesoscale structures (Mass et al. 2002). Such high-resolution forecasts provide physically consistent fields, something that is impossible after human intervention and subjective modification.

Even if full-resolution model grids were available at forecast offices, there is no reason to believe that humans can skillfully downscale model fields to substantially higher resolution in a physically consistent or skillful way. For example, there is little chance that subjectively modified surface temperature and humidity fields would be consistent with altered (or unaltered) clouds fields. Inconsistencies in the altered forecasts will occur along the boundaries between NWS forecast office domains. In areas of complex topography or coastlines, the required effort (and time requirements) to downscale the model fields could be prohibitive. Temporal inconsistencies in the IFPS grids will inevitably develop as well, as time limitations constrain the number of grids that be modified in any shift. Also, with limited high-resolution (in time and space) data assets, why would one expect meteorologists to know the proper structures to be drawn at such resolutions?

An alternative to subjective downscaling is to run models at far higher resolution or to run simpler, less resource intensive, models. It is expected that the cost of running models such as WRF or Eta with a grid spacing of only a few kilometers will be prohibitive for a few years. However, there is a class of simple models, using mass conservation or basic dynamics, that can be run in the lower troposphere, driven by lower-resolution full-physics models. For example, the U.S. Navy Winds on Critical Streamline Surfaces model (Ludwig et al. 1991) uses mass conservation and large-scale inputs to produce high-resolution low-level winds. The development, testing, and evaluation of such downscaling models should be a priority for eventual use in IFPS.

Bias removal *on* forecast grids is another critical issue. The current version of IFPS does not have a means for grid-based removal of model bias before the forecasts are used, and such biases are substantial in all modeling systems. IFPS does allow the spreading of MOS corrections at regional stations, but such an approach will not work well in areas of terrain or land–water contrasts. Objective forecast grid adjustments using previous forecast error at observation locations, land use, and elevation would be far better at bias removal than any subjective attempt, even by an experienced forecaster. To belabor human forecasters with manually removing model biases is a poor use of a vital resource.

A final, but essential, question is why, in the initial application of IFPS, was it necessary to jump to a grid spacing of 5 km, which is substantially greater than NCEP's highest-resolution model (Eta at 12 km)? Considering that IFPS is unproven, the difficulties NCEP has had in distributing 12-km model output to the field, and the apparent problems (noted above) with manual downscaling, why make such a huge leap with a new system?

### c. Weaknesses as a nowcasting tool

Perhaps the greatest failure of the weather forecasting enterprise in the United States is its inability to provide the public with detailed information regarding local weather features and their expected evolution during the next few hours. Meteorologists know a great deal about the short-term evolution of weather conditions that is never communicated to the public. Thus, society has not been able to take advantage of this highly useful information. In contrast to automated systems, human forecasters are particularly well equipped for 0–12-h forecasting (nowcasting) because of our superior image interpretation ability that is coupled with physical understanding of weather systems.

A major roadblock preventing the public from accessing short-term forecasts has been the lack of a suitable information analysis and delivery system, particularly since successful nowcasting demands the rapid communication of detailed information for many locations. Graphical approaches are clearly needed, and IFPS could evolve into a practical, if not exceptional, nowcasting communication tool. IFPS, as currently formulated, is unfortunately not suitable for short-term diagnosis and forecasting. For example, it cannot ingest or make use of radar or satellite imagery, two central nowcasting datasets. Further, it has no ability to extrapolate objectively in time such imagery, a necessary capability.

### d. The use of limited human resources

One of the most undesirable effects of IFPS will be the waste of skilled human forecasters in mind-dulling, and probably unproductive, attempts to modify model grids on an operational basis. Humans cannot integrate the primitive equations in their heads and would be hard-pressed to improve upon full-resolution model forecasts that include bias removal. Human improvement upon calibrated probabilistic forecasts based on a mesoscale ensemble system is even more unlikely.

The IFPS system demands that forecasters create multiparameter high-resolution grids for a number of parameters every hour out to 7 days. This task will produce 168 (24 × 7) grids for at least five parameters (wind speed, direction, temperature, dewpoint, and precipitation) resulting in a minimum of 840 grids! Although not every grid needs to be upgraded by every forecast shift, and time interpolation between grids is possible, this task would take a large amount of time—time that could be better spent on more productive tasks, such as providing detailed short-term forecasts; evaluating model initializations; predictions and trends; and most important, interpreting and explaining the forecasts to the public and other users.

## 3. A revised IFPS

Based on the discussion above, an alternative vision of IFPS is proposed—one that better facilitates the use of human resources and current/future technological capabilities. Major elements of an improved IFPS include the following areas.

1) *Nowcasting enhancements.* IFPS should be enhanced into a full-function nowcasting system that will allow forecasters to construct and communicate short-term (0–12 h) forecasts. Specifically, regional observations, radar imagery, and satellite imagery should be integrated with short-term extrapolation and analysis tools. IFPS should also be able to ingest and display high-resolution analyses such as those produced by the full-resolution Rapid Update Cycle (RUC), the Advanced Regional Prediction System Data Assimilation System (ADAS), the Local Analysis and Prediction System (LAPS), and local mesoscale analyses. Starting with these gridded analyses, forecasters will then build graphical descriptions (probably hourly) of important weather parameters for immediate delivery and use. Because short-term forecasting will be the activity in which human forecasters can make the most significant contribution, it is expected that this work should dominate forecasters' time.

2) *More modest resolution goals and reduced expectations for manual grid intervention.* The grid spacing of IFPS should be no smaller than the highest-resolution operational model (currently 12 km). As noted above, there is no reason to expect that subjective downscaling will be skillful or physically

consistent. Subjective modification of the structures provided by model forecasts should be the *exception,* not the rule. Priority should be given to providing full-resolution model forecast fields to IFPS for all necessary parameters and levels. For the NCEP Eta Model, such fields are available for 3.5 days—one-half of the current IFPS period.

3) *Integration of mesoscale ensembles and full-resolution forecast output into IFPS.* For the period from roughly 12 h to 3 days, the key guidance entering IFPS should be mesoscale ensembles and NCEP full-resolution model output. To that end, the NWS must put more resources into running and distributing mesoscale ensemble forecasts [also known as short-range ensemble forecasts (SREFs)], completing them at least twice a day at full resolution (currently 12 km) for at least 3 days. Then such ensembles should be distributed to all NWS offices and integrated into IFPS. In a similar way, full-resolution operational model grids from a variety of sources (NCEP, the Canadian Meteorological Center, the Fleet Numerical Meteorology Oceanography Center, the Met Office, etc.) should be available on IFPS. It is important to note that NWS offices currently do not receive SREFs through either the Advanced Weather Interactive Processing System or IFPS.

IFPS should be reconstituted to input and use ensemble forecasts easily for the generation and distribution of probabilistic products. For example, mesoscale ensemble forecasts (Stensrud et al 1999; Grimit and Mass 2002) can be used to create gridded probabilistic predictions that can be displayed graphically or used in the construction of automated worded forecasts. As an illustration, IFPS could produce maps of probability of precipitation for amounts greater than 0.01, 0.1, and 1 in. over 6-h forecast periods. Other maps could provide the ensemble mean precipitation amount and some measure of reliability or spread. A reasonable mix of products might include both probabilistic products and the most probable atmospheric fields at forecast times. To create the latter, the forecaster could either select the ensemble mean or use IFPS tools to decide which mesoscale ensemble member or other model output is superior and to use this forecast for graphics generation. As noted above, forecasters should not spend much time altering the structures in deterministic model output, only correcting timing errors in the favored model and modifying critical structures when absolutely necessary. Even less time should be spent altering objectively produced probabilistic products.

4) *Beyond day 3: Use of global ensembles in IFPS.* Beyond day 3, the uncertainty of synoptic and mesoscale deterministic predictions becomes sufficiently large that little confidence can be given to the phasing, position, or even the existence of most mesoscale weather features. At such ranges, the NWS should provide *only* probabilistic products, based on

either an extended mesoscale ensemble system or on NCEP's medium-range ensembles.

5) *Forecast skill guidance.* Forecasters possess a key piece of information that is usually poorly communicated to the public: knowledge of the relative confidence in the forecasts being disseminated. In the past, forecast confidence has been estimated subjectively based on the consistency among several model forecast systems (or the spread of ensemble forecasts), the temporal consistency of forecast solutions (''*d*prog/*dt*''), and the historical skill of operational modeling systems for varying synoptic conditions. The appraisal of expected forecast skill is typically provided through often cryptic (but still highly useful) forecast discussions. Recent research on both the synoptic scale (e.g., Buizza 1997) and the mesoscale (e.g., Grimit and Mass 2002) has indicated the potential for objective prediction of forecast skill based on the spread of ensemble forecasts, at least for low- and high-spread situations.

IFPS needs to be enhanced so as to facilitate the communication of forecast reliability. This could include a forecaster providing a subjective measure of the forecast reliability (perhaps on a scale of 1–10) for each forecast hour that would be tagged to the relevant graphics, or the provision of reliability graphics produced objectively, perhaps based on forecast spread. In any case, the importance of the forecast discussion as a means for communicating forecasters' evaluation of the situation remains undiminished. Providing graphical forecasts (either probabilistic or deterministic) without explanation and analysis is like watching a movie without the sound—one may have an idea of what is going on, but subtleties and true understanding are often lost.

## 4. The changing role of the human forecaster

Implicit in the proposed IFPS modifications is a vision of the changing role of human forecasters. Objective systems based on ensembles and statistical postprocessing will provide the foundation for forecasts longer than approximately one-half day, leaving forecasters to address tasks for which they can make a real contribution. These tasks are as follows.

1) Provision of advisories, watches, and warnings of significant weather events that are a substantial threat to person or property.
2) Very short-term forecasting (0–12 h), whereby subjective imagery interpretation can be used to greatest advantage and simple temporal extrapolation can be of great value.
3) Monitoring of the objective forecasting systems and intervening when necessary. Although forecasters will not, in general, be able to improve upon the synoptic and mesoscale aspects of objective 1–7-day forecasts (particularly ones in which numerical models are cou-

pled to statistical postprocessing), there will be infrequent situations in which the models and statistical guidance are clearly in error. An example of such a situation is one in which the lack of data over the Pacific Ocean results in all ensembles having a similar, apparently bogus, solution in which a system is coming in too fast. A human forecaster, examining a wide range of satellite imagery, might apply a time shift to the forecast fields used in IFPS dissemination. Subjective correction of structures is far more difficult and of doubtful value. Even if forecasters cannot improve upon the forecasts, they can flag such events and communicate the problem to users.

4) Modication of forecasts for phenomena that are unresolved or poorly simulated by the models. Although model resolution is improving rapidly, there will always be unresolved circulations of potential importance. For example, even if the Eta Model was run at 4-km grid spacing, a resolution not planned for several years, such spacing would only be adequate for phenomena of scales of approximately 20–30 km or greater. In regions where smaller-scale phenomena can be crucial (e.g., in and near topography or coastlines) subjective human intervention will still be necessary. An example of such a situation is gap flow in the Columbia River Gorge, where adequate simulation of gap winds requires grid spacing of approximately 1 km (Sharp and Mass 2002). Until such resolution is available operationally, forecasters will have to provide information about the position and intensity of the narrow swath of strong winds that can occur in the gorge exit region—using IFPS as one means to disseminate this information.

5) Interpretation and explanation of the forecasts to the public and the user community. As the skill and information content provided by the NWS through IFPS increases, the need for human forecasters to interpret the information and to interact with the public and other users will be also be enhanced. It is expected that the improved accuracy and specificity of forecasts will greatly increase the user community for NWS products and thus will increase demands on NWS staff for interpretation and explanation. This public-interface role of NWS staff will be particularly demanding during damaging and dangerous weather, when the media, emergency managers, public utilities, airports, and others will require expert assistance in evaluating the potential threat.

## 5. Summary

We are entering an era in which high-resolution models realistically simulate regional mesoscale circulations, when mesoscale ensembles produce calibrated regional-scale probabilistic guidance, and forecasters can no longer consistently ''beat'' objectively produced forecasts. The frequent use of human beings to labori-

ously alter deterministic forecasts for a week into the future would be a serious mistake that would lessen forecasters' time for more productive work. IFPS must be altered to facilitate short-term forecasting and the communication of such forecasts. It should also evolve into a more probability-capable platform that can make use of ensemble information and can disseminate probabilistic information. Last, human forecasters must be left with sufficient time to fill an irreplaceable role—to explain and interpret the probabilistic and deterministic forecasts created by automated numerical weather prediction systems and to provide critical advisories, watches, and warnings.

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